U.S. Department of Energy
National Energy Technology Laboratory

Early Entrance Co-Production Plant – Decentralized Gasification Cogeneration Transportation Fuels and Steam From Available Feedstocks

DOE Cooperative Agreement DE-FC26-00NT40693

Quarterly Technical Progress Report
July to September 2001

Waste Processors Management, Inc.
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DISCLAIMER

ABSTRACT

Waste Processors Management, Inc. (WMPI), along with its subcontractors Texaco Power & Gasification, SASOL Technology Ltd., and Nexant Inc. entered into a Cooperative Agreement DE-FC26-00NT40693 with the U. S. Department of Energy (DOE), National Energy Technology Laboratory (NETL) to assess the techno-economic viability of building an Early Entrance Co-Production Plant (EECP) in the United States to produce ultra clean Fischer-Tropsch (FT) transportation fuels with either power or steam as the major co-product. The EECP designs emphasize on recovery and gasification of low-cost coal waste (culm) from coal clean operations and will assess blends of the culm and coal or petroleum coke as feedstocks.

The project is being carried out in three phases. Phase I involves definition of concept and engineering feasibility study to identify areas of technical, environmental and financial risk. Phase II consists of an experimental testing program designed to validate the coal waste mixture gasification performance. Phase III involves updating the original EECP design, based on results from Phase II, to prepare a preliminary engineering design package and financial plan for obtaining private funding to build a 5,000 BPD coal gasification/liquefaction plant next to an existing co-generation plant in Gilberton, Schuylkill County, Pennsylvania.

The current report is WMPI's second quarterly technical progress report. It covers the period performance from July 1, 2001 through September 30, 2001.

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1.1 INTRODUCTION

WMPI, along with its subcontractors Texaco, Sasol, and Nexant entered into a Cooperative Agreement DE-FC26-00NT40693 with the U. S. Department of Energy (DOE), National Energy Technology Laboratory (NETL), to assess the technical and economic viability of building an Early Entrance Co-Production Plant (EECP) in the U. S. to produce ultra clean Fischer-Tropsch (FT) transportation fuels with either power or steam as the major co-product. The EECP design emphasizes on recovery and gasification of low-cost coal wastes (culm) from coal cleaning operations, and will assess blends of the culm with coal or petroleum coke as feedstocks. The project has three phases.

1.1.1 Phase I – Concept Definition and RD&T Planning

Phase I objectives include concept development, technology assessment, conceptual designs and economic evaluations of a greenfield commercial co-production plant and of a site specific demonstration EECP to be located adjacent to the existing Gilberton Power Station. There are very few expected design differences between the greenfield commercial co-production plant versus the EECP plant other than:

- The greenfield commercial plant will be a stand alone FT/power co-production plant, potentially with larger capacity than the EECP to take full advantage of economies of scale.
- The EECP plant, on the other hand, will be a nominal 5,000 bpd plant, fully integrated into the Gilberton Power Company's Cogeneration Plant's existing infrastructure to reduce cost and minimize project risks. The Gilberton EECP plant will be designed to use eastern Pennsylvania anthracite coal waste and/or a mixture of culm and other fuels as feedstock.

Phase I includes 11 tasks and the following major deliverables.

- A project management plan.
- A process feasibility design package with sufficient details to determine order-of-magnitude cost estimates for preliminary economic and market analyses.
- A preliminary environmental and site analysis.
- A Research, Development and Testing (RD&T) plan for Phase II tasks.
- A preliminary project financing plan.

1.1.2 Phase II – R&D and Testing

The Phase II objective is to perform research, development and process performance verification testing of any design deficiencies identified in Phase I. Due to the relative maturity of the two key technologies (Texaco's coal gasification and SASOL's FT) proposed for the EECP designs, Phase II activities will focus on feedstock characterization and gasification process performance testing rather than research and development. Specific Phase II goals include:

- Characterization of anthracite culm and its mixture with other fuels as feedstocks for the Texaco gasifier.
- Gasification performance (pilot plant) testing of design anthracite culm feedstocks at an existing Texaco facility to verify its performance.

1.1.3 Phase III – Preliminary Engineering Design

The objective in Phase III is to upgrade the accuracy of the Phase I site-specific Gilberton EECP capital cost from plus or minus 35% to plus or minus 20%. The increased cost estimation accuracy is achieved by updating the Phase I inside battery limits (ISBL) processing plant design packages to incorporate Phase II findings, by refining the outside battery limits (OSBL) utility and offsite support facility design packages to include final and updated ISBL unit demands, by obtaining actual budgetary quotes for all major equipment, and by further engineering to define the actual bulk commodities requirements.

The upgraded Phase III capital cost estimate, together with the updated operating and maintenance cost estimate, are crucial elements to finalize the EECP Project Financing Plan needed to proceed with detailed engineering, procurement and construction of the EECP.

The Phase III goals and deliverables include the development of:

- Preliminary Engineering Design package of the EECP.
- A Project Financing Plan.
- An EECP Test Plan.

The project scope of work consists of sixteen tasks organized into the three phases as shown in Table 1.1. The table also shows the project team members responsible for the leading role for each task. The specific task description details were discussed in the Project Management Plan.

1.2 SUMMARY

The main technical activities performed during the current reporting period include work in the following tasks.

- Phase I, Task 3 – System Technical Assessment
    - Feedstock Ash Fusion Temperature Evaluation
    - Preliminary EECP Plant Balances

Table 1-1

Scope of Work Task Summary

Phase/Task	Description	Task Leaders
Phase I	**Concept Definition and RD&T Planning**	
Task 1	Project Plan	Nexant
Task 2	Concept Definition, Design Basis & EECP Process Configuration Development	Nexant
Task 3	System Technical Assessment (Trade-off Analysis)	Nexant
Task 4	Feasibility Study Design Package Development	Nexant (w/individual Process Design package from Texaco and Sasol)
Task 5	Market Assessment	Texaco
Task 6	Preliminary Site Analysis	WMPI and Consultants
Task 7	Preliminary Environmental Assessment	WMPI and Consultants
Task 8	Economic Assessment	WMPI and Consultants
Task 9	Research Development and Test Plan	Texaco
Task 10	Preliminary Project Financing Plan	WMPI and Consultants
Task 11	Phase I - Concept Report	Nexant
Phase II	**R&D and Testing**	
Task 1	Feedstock Mix Characterization and Gasification Performance Verification	Texaco (w/ support from Nexant and WMPI)
Task 2	Update RD&T Plan	Texaco
Phase III	**EECP Engineering Design**	
Task 1	Preliminary Engineering Design Package Development	Nexant – with a) Texaco – Gasification Design Package b) Sasol – FT Design Package c) Nexant – BOP and cost estimate
Task 2	Project Financing Plan	WMPI and Consultants
Task 3	EECP Test Plan	Nexant

- Phase I, Task 4 – Feasibility Study Design Package Development,
- Phase I, Task 5 – Market Analysis,
- Phase I, Task 6 – Preliminary Site Analysis
    - Assessment of FT Reactor Transport and Installation

Results and accomplishments of each are described in more detail in the following sections.

Section 2 Phase I Task 3 – System Technical Assessment

Under this task, critical design issues identified in Task 2 were assessed in more detail. Preliminary heat, material and utility balances were carried out, based on process performance estimates and utility demands from Texaco and Sasol for the gasification and FT synthesis section respectively, with an objective to establish an integrated process/utility model for future optimization trade-off analysis, and to provide preliminary emission data needed for Phase I Task 7 planning.

2.1 Ash Fusion Temperature Prediction for EECP Coal Feeds

Anthracite culm has high ash contents and the ash (rich in silicon and aluminum oxide) has a high fusion temperature. Both factors, left uncorrected, can have an adverse effect on the performance of Texaco's entrained, downflow slagging, gasifier. Thus the ash fusion temperature (along with its molten viscosity) is a major design parameter, and could strongly influence the EECP's technical and economic viability. Laboratory test data shows that the ash fusion temperature of the anthracite culm feed exceeds Texaco gasifier's normal operating temperature (about 2,500° F for quench mode operation), and addition of a flux material (fluxant) such as limestone will be needed to reduce the ash fusion temperature. Ability to estimate or predict the EECP feed ash fusion temperature and the amount of fluxant required for Texaco gasification operation is of importance.

The work performed in this period examines methods to estimate ash fusion temperatures for several feedstocks. The methodology is intended to facilitate selection of alternate blended feeds, and to provide guidelines for the amounts of flux material needed. The results from a review of empirical equations that correlate ash fusion (fluid) temperatures against ash compositions are reported. Empirical equations were identified as means to screen blends of feedstocks and flux materials for the EECP project.

2.1.1 Summary of Results and Applications

After an evaluation of about 100 samples and their ash composition vs. ash fusion temperature relationship, the Winegartner and Rhodes (WR) correlation is selected for estimating ash fusion temperatures (fluid temperature in a reducing atmosphere) for the EECP design study. It is recommended that 150°F be added to the WR estimated value to allow for uncertainty in the estimate.

Examples are provided below for the application of the WR correlations to predict the ash fusion fluid temperature as a function of limestone addition for the potential EECP feeds. The information may be used as part of the Phase I design, especially with respect to oxygen consumption, and to provide guidelines for limestone addition parameters as part of the Phase II RD&T activities. The examples are for the following feedstocks.

- 100% anthracite culm, ash fusion fluid temperature (AFFT) versus limestone addition.

- Blend of 75% anthracite culm with 25% petroleum coke, ash fusion fluid temperature versus limestone addition.

Figure 2-1 is a graph of the WR predicted ash fluid temperature (AFFT) versus the weight percent of limestone flux added to the 100% anthracite culm (20% by weight ash content). Two actual (WMPI measurements) data points, 100% anthracite culm and 95% anthracite culm with 5% limestone, are also shown. The flat portion of the curves are the minimum ash AFFT, approximately 2290° F with 13 to 26 weight percent limestone added, or the equivalent 1.34 to 0.57 ash-to-limestone weight ratio. Using a maximum 2520 °F gasification temperature and a 150° F uncertainty allowance for correlation inaccuracies, approximately 8% limestone (2.30 ash-to-limestone weight ratio) results in a AFFT of 2370° F.

Figure 2-2 is a similar plot for a 75% anthracite culm and 25% petroleum coke feed. The estimated ash fluid temperatures are graphed versus the weight percent limestone addition. A minimum AFFT is approximately 2290° F with 10 to 20 weight percent limestone added, or an equivalent 1.35 to 0.60 ash-to-limestone weight ratio. For a maximum 2520° F gasification temperature and a 150° F design allowance, approximately 6 percent by weight of limestone (2.35 ash-to-limestone weight ratio) gives an estimated AFFT of 2370° F.

Figure 2-1
100 % Anthracite Culm
Ash Fusion Fluid Temperature Versus Limestone Addition

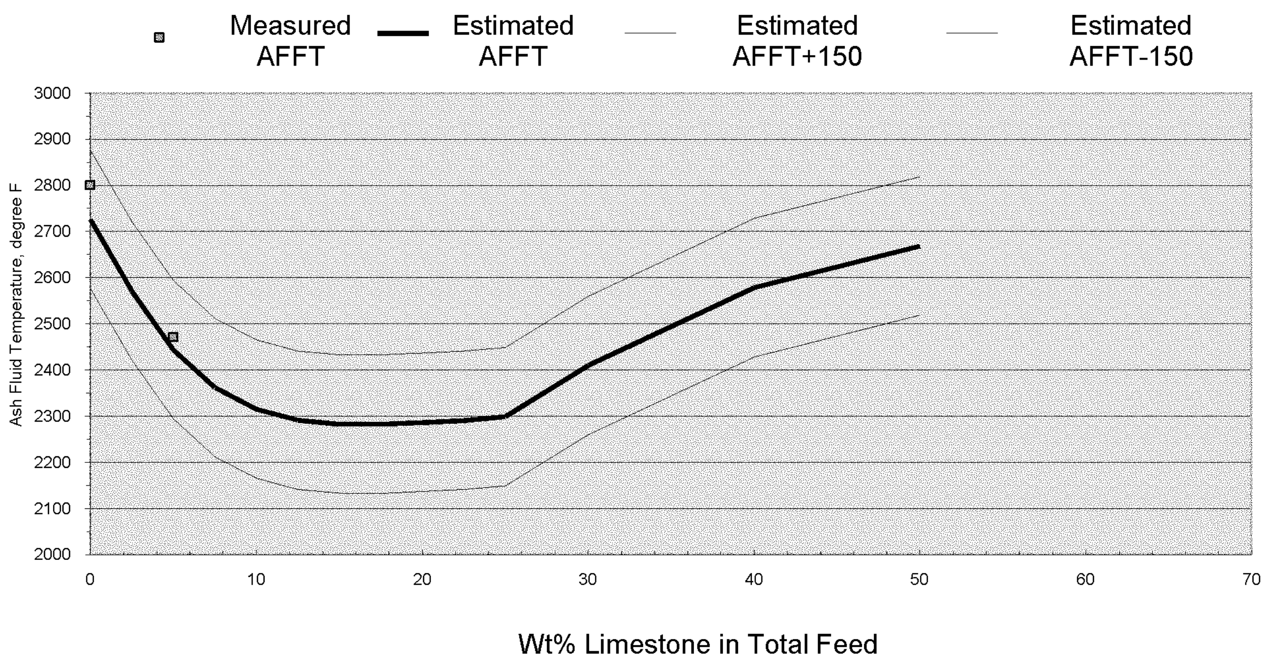
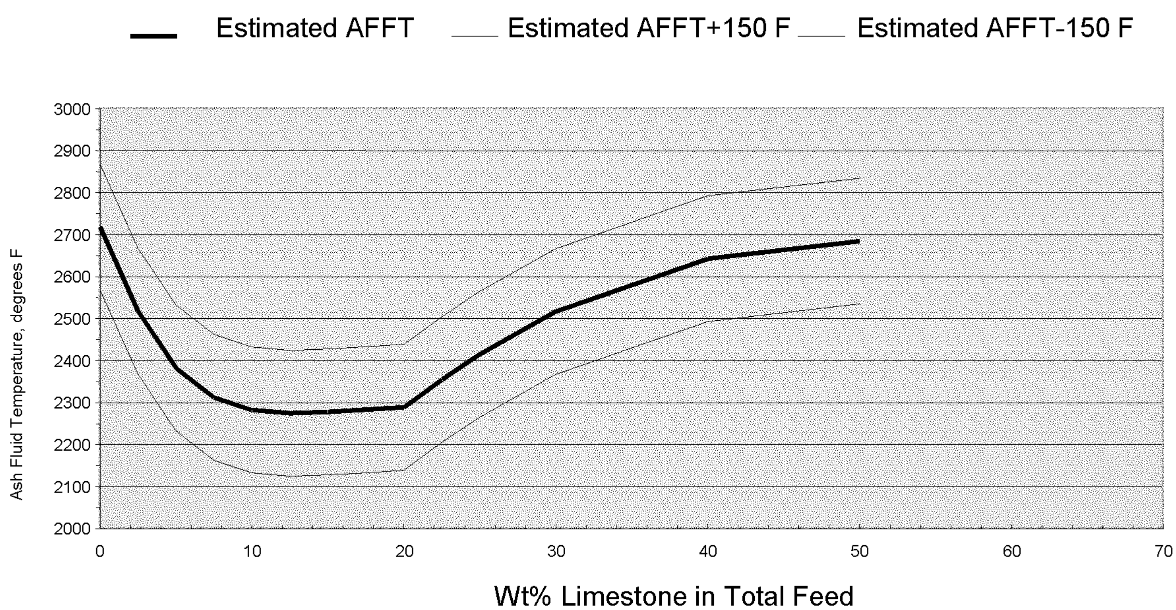
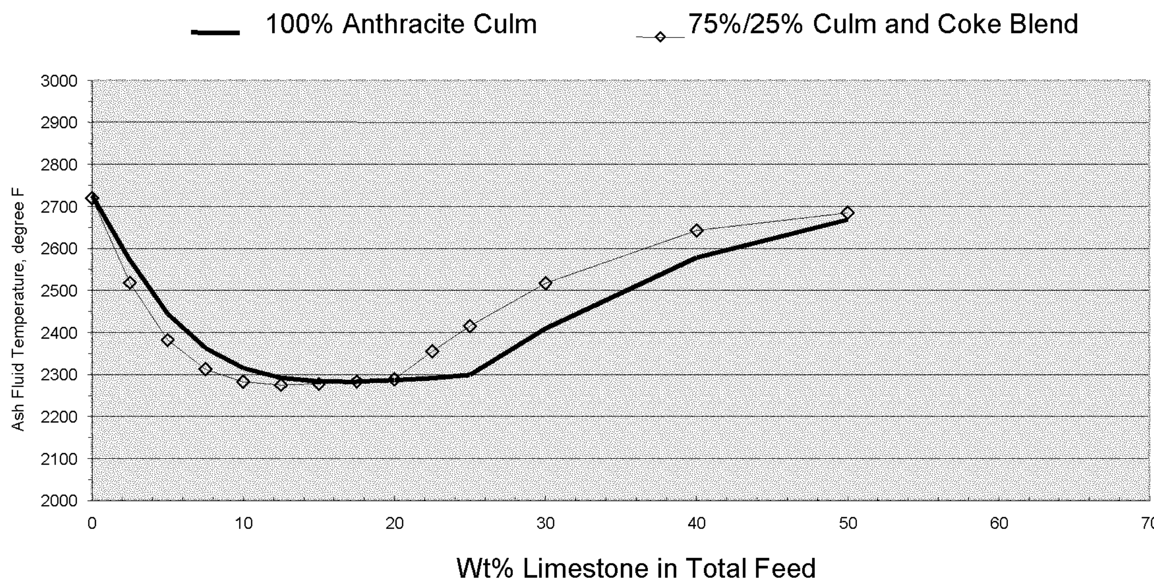


Figure 2-2
Blend of 75% Anthracite Culm plus 25% Petroleum Coke
Ash Fusion Fluid Temperature Versus Limestone Addition



It is noted that the anthracite culm and coke blend has a lower total ash content (15% by weight) than the 100% anthracite culm (20% by weight), and thus less limestone addition is anticipated for the blend. However, the ash to limestone weight percent ratio for the coal feed blend should be about the same for any given blend's AFFT. In Figures 2-1 and 2-2, the relative weight ratio of feed ash-to-limestone addition is about the same for the two different feeds at a given AFFT. Figure 2-3 superimposes the WR AFFT estimated ash fluid temperature versus limestone addition for 100% anthracite culm and for anthracite culm and petroleum coke blend. The offset lines reflect the feed ash content difference.

Figure 2-3
Comparison of 100% Anthracite Culm and Blend of Culm with Petroleum Coke
Ash Fusion Fluid Temperature versus Limestone Addition



2.1.2 Methodology Review and Ash Fusion Temperature Correlations

Ash fusion temperatures give an indication of the softening and melting behavior of fuel ash. Fusion temperatures at one time were quite subjectively measured, but this has been addressed by the development of automated techniques for performing the measurements. Fusion temperatures are valuable guides to the high-temperature behavior of the fuel's inorganic material. Fusion temperatures typically are measured at four defined points under both reducing and oxidizing conditions. These points are defined as follows.

- Initial deformation temperature (IT): This is the temperature at which the point of sample cone begins to round.
- Softening temperature (ST), sometimes called the spherical temperature, is defined as the point where the base of the cone is equal to its height.
- Hemispherical temperature (HT): The temperature at which the base of the cone is twice its height.
- Ash fusion fluid temperature (AFFT): The temperature at which the cone has spread to a fused mass no more than 1.6 mm in height.

Generally, a temperature under reducing conditions should be equal to or lower than the corresponding temperature under oxidizing conditions. The difference in these temperatures typically increases with increasing iron content in the ash.

Three empirical equations correlating ash fusibility under reducing atmosphere against ash compositions were reviewed.

- Sondreal and Ellman (1975) - Softening temperature (ST) versus ash composition
- Bryers and Taylor (1976) - Hemispherical fusion temperature (HT) versus ash composition
- Winegartner and Rhodes (1975) - Initial deformation temperature (IT), ST, HT, Fluid temperature (AFFT), and AFFT-IT difference (Delta AFFT/IT) versus ash composition.

Of the above three, only the Winegartner and Rhodes (WR) correlation predicts AFFT based on ash compositions. In addition, the WR offers two different ways to estimate AFFT, 1) direct WR ($AFFT_1$) calculates AFFT as a function of ash composition and 2) indirect WR ($AFFT_2$) calculates AFFT as IT + Delta AFFT/IT, with IT and Delta AFFT/IT being functions of ash composition. The review uses the two WR correlations for predicting ash AFFT based on ash compositions.

The general formats of the WR equations are:

1. $AFFT_1 = C_{AFFT} + \Sigma\, ai_{(AFFT)} * xi$, ^{o}F

and

2. $AFFT_2 = (IT) + (Delta\ AFFT/IT) = (C_{IT} + \Sigma\, ai_{(IT)} * xi) + (C_{Delta} + \Sigma\, ai_{(Delta)} * xi)$, ^{o}F

Where C_{AFFT}, C_{IT} , C_{Delta}, $ai_{(AFFT)}$, $ai_{(IT)}$ and $ai_{(Delta)}$ are constants with xi being mole% i-th ash components defined by the WR correlations. The WR correlations and the associated constants and variables are those defined in the "Coal Conversion Systems Technical Data Book", prepared by Institute of Gas Technology (now the Gas Technology Institute, or GTI) for the U.S. Department of Energy.

2.1.2.1 Coal Ash Fusion Data

In order to test the ash fusion estimating methodology, actual data from laboratory measurements using accepted ASTM procedures are required. The following sources of ash compositions and ash fusion temperatures data are used for this study.

Coals from Pennsylvania counties as listed under the "Elemental Composition and Fusibility of Ash of Large Deposits of US Coals" section in DOE's "Coal Conversion Systems Technical Data Book". Only samples with both ash compositions and measured fusion temperatures are used. A total of 60 data points are available.

Coal samples from Nexant's in-house databank that contain both ash compositions and measured ash fusion temperatures. A total of 30 data points, including both domestic and foreign coals, are available.

Data for potential EECP feedstocks such as anthracite culms, Pittsburgh bituminous coal, petroleum cokes, limestone and other flux materials supplied by WMPI. Properties of these potential blending feedstocks are summarized in Tables 2-1 and 2-2.

Table 2-1
Potential EECP Feedstocks
WMPI Data

Description & Cases	Anthracite Culm Tailings			Bituminous Coal	Bituminous Coal	Coke Fluid	Petroleum Coke
	Design Case	Alternate Case 1	Alternate Case 1				
Feedstock Sample ID	A3	2A	A8	Hawk Mtn	Warner	Koch	P1
Proximate Analysis, wt%:							
Moisture	1.92	11.96	1.86	9.60	5.47	11.67	0.36
Volatile Matter	7.21	5.72	10.69	20.05	21.23	6.20	11.90
Fixed Carbon	71.25	64.72	67.83	52.27	54.88	81.48	85.95
Ash	19.62	17.61	19.63	18.08	18.42	0.65	1.79
Ultimate Analysis, wt% dry:							
Carbon	72.54	74.48	69.27	66.71	68.55	88.56	85.93
Hydrogen	2.32	2.30	3.46	4.15	4.13	1.80	3.90
Nitrogen	0.87	0.87	1.18	1.12	1.15	1.71	1.27
Sulfur	0.38	0.27	0.25	3.29	4.86	6.18	5.37
Chloride	---	---	---	---	---	---	---
Oxygen	3.89	2.09	5.84	4.73	1.82	1.01	1.73
Ash	20.00	20.00	20.00	20.00	19.49	0.74	1.80
HHV, Btu/lb(dry basis)	11,119	11,942	11,269	11,843	12,439	14,191	15,251
Ash Analysis, wt%:							
Silica, SiO_2	57.10	54.30	53.00	52.54	35.15	18.20	59.40
Aluminum Oxide, Al_2O_3	28.20	26.00	26.70	25.47	24.80	6.20	10.90
Iron Oxide, Fe_2O_3	5.69	4.95	8.41	14.80	29.39	4.10	12.10
Calcium Oxide, CaO	0.50	0.10	0.50	0.47	3.72	4.17	4.10
Magnesium Oxide, MgO	0.20	0.61	0.13	0.16	0.30	2.03	1.78
Sodium Oxide, Na_2O	0.62	0.91	0.37	0.16	0.42	1.52	1.56
Potassium Oxide, K_2O	2.97	2.45	2.77	2.06	1.72	0.49	1.21
Titanium Oxide, TiO_2	2.43	1.86	1.86	1.52	1.27	0.19	1.71
Nickel Oxide, NiO	---	---	---	---	---	2.25	---
Vanadium Pent-oxide, V_2O_5	---	---	---	---	---	47.17	---
Phosphorus Pent-oxide, P_2O_5	---	---	---	---	0.34	1.60	---
Sulfur Trioxide, SO_3	2.29	4.10	0.02	2.82	1.68	10.68	2.08
Others	---	4.72	6.24	---	1.21	1.40	5.16
Ash Fusion Temp in Reduced Atmosphere (ASTM D-1857), °F:							
Initial Deformation	2,740	2,450	2,269	2,490	1,949	> 2,700	2,131
Softening	2,790	2,475	2,688	2,535	2,090	> 2,701	2,489
Fluid	> 2,800	2,667	> 2,800	2,633	2,265	> 2,702	2,697

Table 2-2
Potential Flux Properties

Analysis Data	Description and Source Limestone Meckley	 Iron Oxide Hawk Mtn	 CFB Fly Ash WMPI
Proximate Analysis, wt%			
Moisture	---	10.56	---
Volatile Matter	36.84	27.64	9.30
Fixed Carbon	---	---	---
Ash	63.16	61.8	90.70
Ultimate Analysis, wt% dry			
Carbon	10.04	8.43	2.54
Hydrogen	---	---	---
Nitrogen	---	---	---
Sulfur	---	---	---
Chloride	---	---	---
Oxygen	26.80	22.47	6.76
Ash	63.16	69.1	90.70
HHV, Btu/lb(dry basis)	0	0	0
Ash Analysis, wt%			
Silica, SiO_2	15.40	3.96	55.70
Aluminum Oxide, Al_2O_3	4.95	2.12	25.80
Iron Oxide, Fe_2O_3	3.10	15.90	7.15
Calcium Oxide, CaO	71.80	46.30	---
Magnesium Oxide, MgO	1.80	7.68	0.15
Sodium Oxide, Na_2O	0.61	0.20	0.68
Potassium Oxide, K_2O	0.84	0.04	2.62
Titanium Oxide, TiO_2	0.25	0.14	2.29
Phosphorus Pentoxide, P_2O_5	---	---	---
Sulfur Trioxide, SO_3	1.20	0.65	---
Others	0.05	23.01	5.61

Data was provided by WMPI for two laboratory synthesized blends, with one being 95% anthracite culm with 5% limestone, and the second 95% anthracite culm with 2.5% limestone plus 2.5% Circulating Fluidized-Bed Boiler (CFB) fly ash. The measured ash fusion temperatures for the WMPI blends are listed below in Table 2-3.

Table 2-3
Ash Fusion Temperatures
Laboratory Synthesized Blends

Data Items	Composition, Weight Percents	
	Blend #1	Blend #2
Anthracite Culm	95	95
Limestone	5	2.5
CFB Fly Ash	0	2.5
	Ash Fusion Temperature °F, Reducing Atmosphere	
	Blend #1	Blend #2
Initial Deformation	2,398	2,398
Softening	2,426	2,503
Hemispherical	2,456	2,643
Fluid	2,471	2,696

The as-reported ash compositions from the above data sources were normalized to eliminate undefined ash components before applying the WR correlations to calculate the IT and AFFT.

2.1.2.2 Correlation Assessment and Accuracy

To evaluate the accuracy of the two WR correlations, ash fusion temperatures are calculated using the WR correlations, and then are compared with ash fusion temperature data measured by ASTM Test D-1857. As a comment on the limits of accuracy, the ASTM D-1857 test for ash fusion temperatures under reducing atmosphere has the following inherent accuracy limits:

	Repeatability °F (Same Laboratory)	Reproducibility °F (Different Laboratory)
IT = Initial Deformation Temperature	+/- 50	+/- 125
ST = Softening Temperature	+/- 50	+/- 100
HT = Hemispherical Temperature	+/- 50	+/- 100
AFFT = Fluid Temperature	+/- 50	+/- 150

For comparisons of the laboratory ash fusion temperature data ($AFFT_m$) and the values calculated by the correlations ($AFFT_p$), simple bar graphs are presented to visually display the information. The graphs also show lines for a band plus 150^o F and minus 150^o F on each side of the laboratory data. These two lines also bracket the inherent reproducibility limits of ASTM D-1857.

In addition to the graphs, the comparison of the correlations and actual data are reported in average deviations and in standard deviations. The deviations are defined below.

$$\text{Average Deviation} = \{ {}_1\Sigma^n \, AFFT_p(i) - AFFT_m(i) \} / n$$

and

$$\text{Standard Deviation} = \{ {}_1\Sigma^n \, [(AFFT_p(i) - AFFT_m(i)]^2 \} / (n - 1)$$

Pennsylvania Coals

To review the correlation methodology, ash fusion fluid temperatures estimated by the WR correlations are compared with the temperatures reported for coals from large deposits in Pennsylvania. The Pennsylvania coal data is from the "Elemental Composition and Fusibility of Ash of Large Deposits of US Coals" section of DOE's "Coal Conversion Systems Technical Data Book". Figure 2-4 compares the direct WR $AFFT_1$ correlation values with the laboratory measurements for Pennsylvania coals listed in the DOE publication. The average deviation is -186^o F and the standard deviation is 214^o F. As evident in the figure and by the large negative average deviation, the direct WR $AFFT_1$ correlation tends to underestimate the ash fluid temperature compared to measured values.

Figure 2-4
Comparison of Direct WR Correlations and Measured Pennsylvania Coal Data

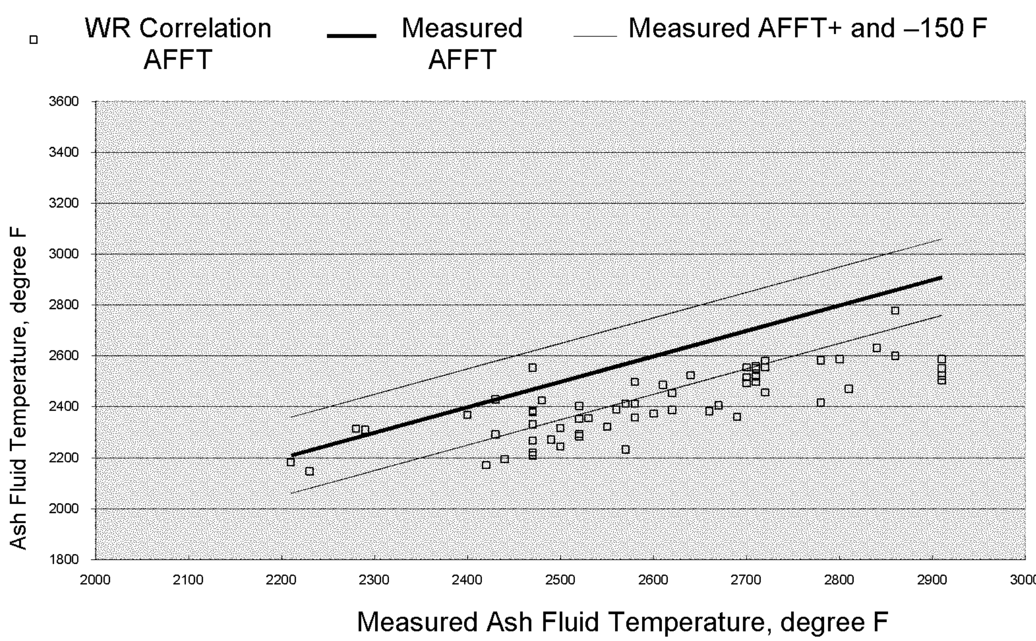
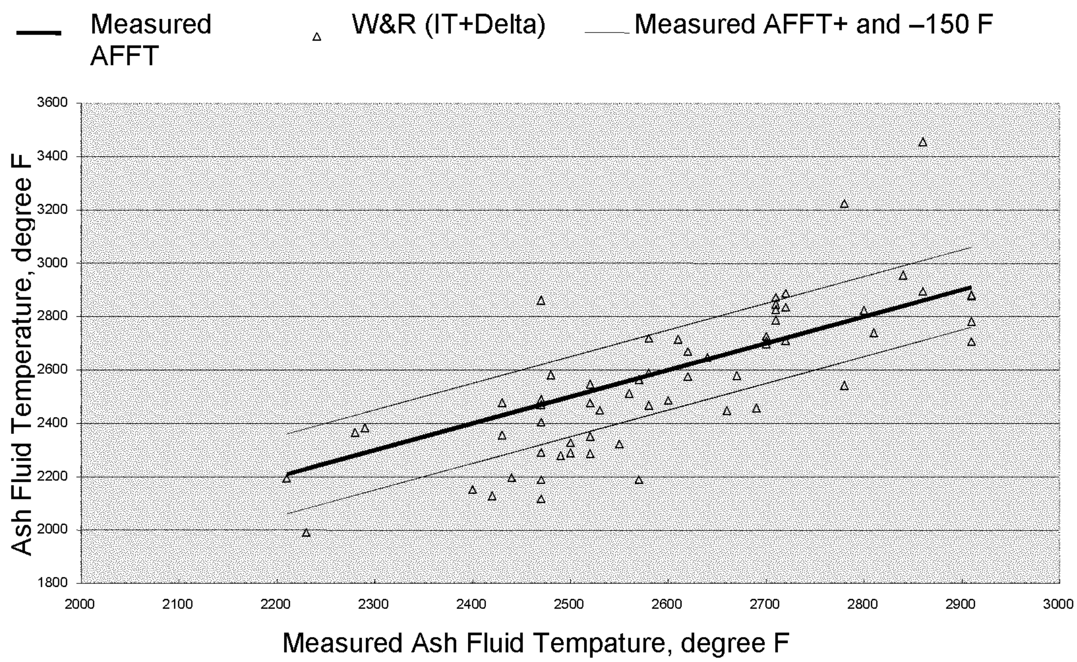


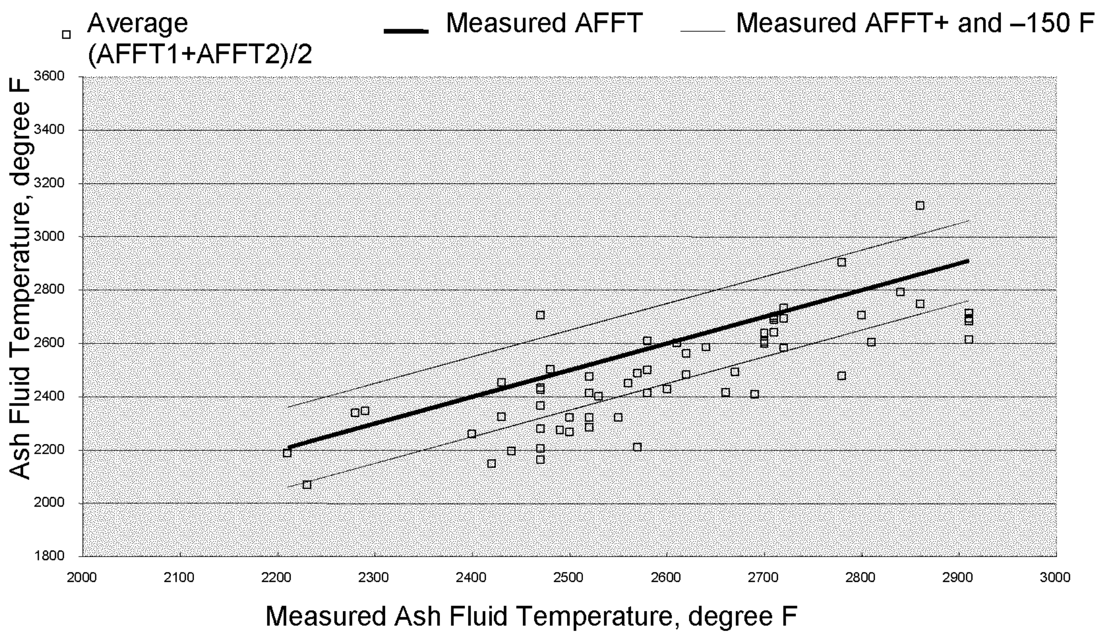
Figure 2-5 compares the indirect WR $AFFT_2$ correlation against the measured AFFT values. The average deviation is -36^o F and the standard deviation is 185^o F. As shown in Figure 2-4, the indirect WR $AFFT_2$ predictions appear more scattered than the direct WR $AFFT_1$ correlations. The negative average deviation indicates that the indirect WR $AFFT_2$ correlation also tends to underestimate the ash fluid temperatures, but not by as much as the direct WR $AFFT_1$.

Figure 2-5
Comparison of Indirect WR Correlations and Measured Pennsylvania Coal Data



Ideally, the direct WR $AFFT_1$ correlation and the indirect WR $AFFT_2$ correlation should give the same estimates since both were regressed from the one set of data. But the figures show they are somewhat different. As a compromise, averages of the two estimates ($AFFTavg = (AFFT_1 + AFFT_2) / 2$) were also plotted. Figure 2-6 compares the average WR estimates of AFFT against the measured AFFT. The average deviation in this case is -111°F and the standard deviation is 168°F. As shown in Figure 2-6, the averages of the $AFFT_1$ and $AFFT_2$ estimates are less scattered than the indirect WR $AFFT_2$ predictions. The negative average deviation shows that the average correlation value still underestimates the measured ash fluid temperatures.

Figure 2-6
Comparison of Average WR Correlations and Measured Pennsylvania Coal Data



Other Coal Samples

In addition to the ash fusion temperature and composition data from the DOE technical data book, approximately 30 coal samples from Nexant's in-house database were used to compare the WR correlations versus measured ash fluid temperatures. Nexant's data are accumulated from past projects and publications, and include coals from around the world. Figure 2-7 compares the direct WR $AFFT_1$ correlation against the actual AFFT for the Nexant in-house coal samples. The average deviation is -63^{o} F and the standard deviation is 130^{o} F. As shown in Figure 2-7 and by the large negative average deviation, the direct WR $AFFT_1$ correlation continues to underestimate the measured ash fluid temperature.

Figure 2-8 compares the indirect WR $AFFT_2$ correlation against the measured AFFT. The average deviation is $+83^{o}$ F and the standard deviation is 325^{o} F. The indirect WR $AFFT_2$ estimates are more scattered than the direct WR $AFFT_1$ correlations and the negative average deviation indicates that the correlation underestimates the measured ash fluid temperatures. The large standard deviation indicates that indirect WR $AFFT_2$ correlation is less accurate than the direct WR $AFFT_1$ correlation.

Figure 2-7
Comparison of Direct WR Correlations and Nexant International Coal Data

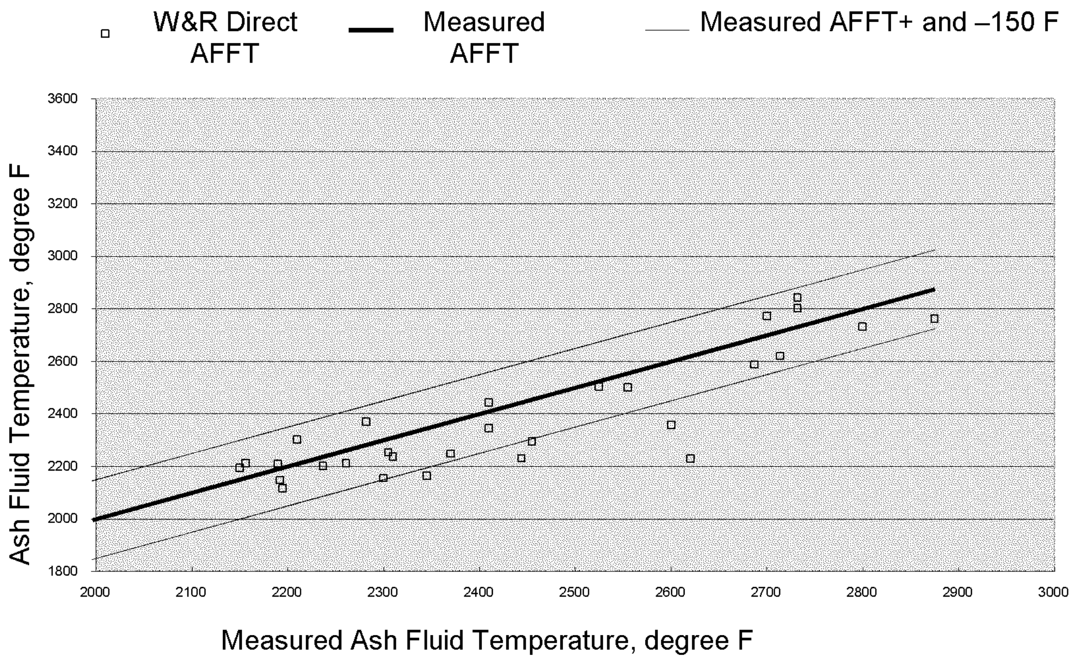


Figure 2-8
Comparison of Indirect WR Correlations and Nexant In-House Coal Data

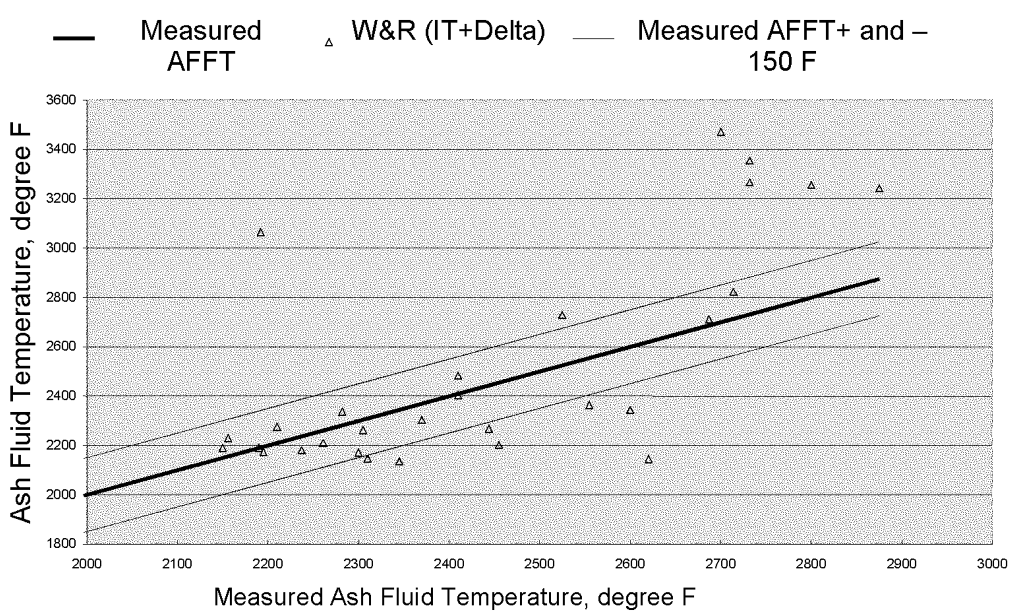
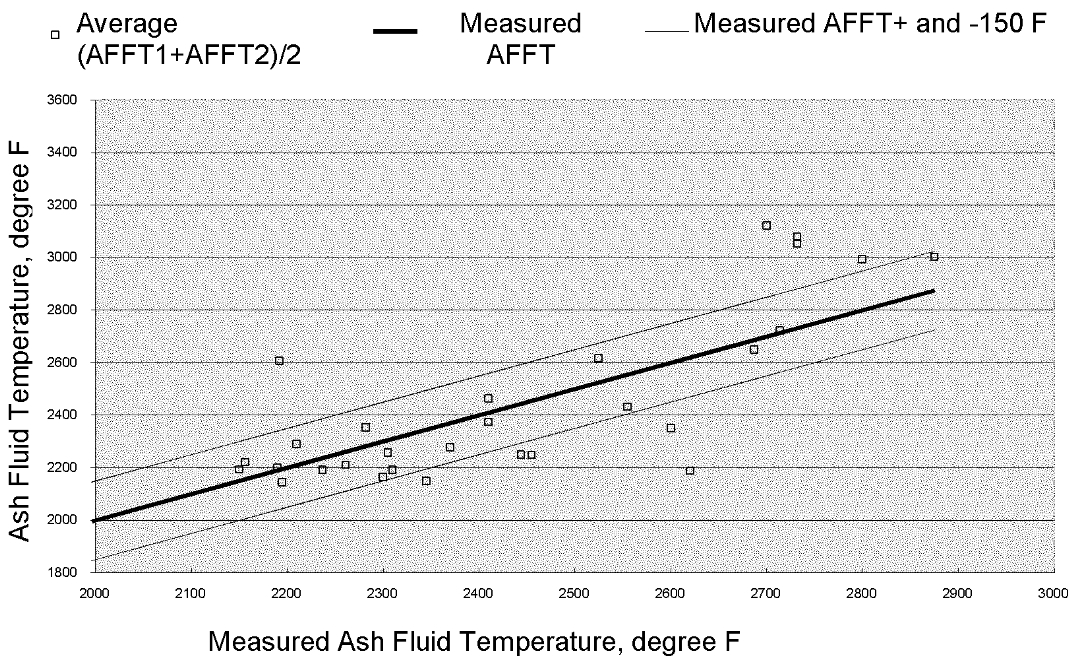


Figure 2-9 compares the average WR $AFFT_1$ and WR $AFFT_2$ correlations with the measured AFFT. The average deviation is +10° F and the standard deviation is 195° F. The average $AFFT_1$ and $AFFT_2$ correlations are less scattered than the indirect WR $AFFT_2$, but more than the direct WR $AFFT_1$ correlations. Although a smaller average deviation indicates that the average value is closer to the measured AFFT value, a larger standard deviation indicates that it is no better than the direct WR $AFFT_1$ predictions.

Figure 2-9
Comparison of Average WR Correlations and Nexant In-House Coal Data



EECP Coal Feeds

Following the review and assessments of coal properties from Nexant and other sources, the WR correlations were compared with actual ash fluid temperatures measured for potential EECP feedstocks listed in Table 2-1 and 2-2. Figure 2-10 compares the direct WR $AFFT_1$ correlation and the measured AFFT for the potential EECP blending feedstocks. The average deviation is –108° F and the standard deviation is 175° F. As shown in Figure 2-10, the estimated values for fusion temperatures are within the plus or minus 150° F reproducibility accuracy limit of the ASTM D-1857 test. The negative average deviation indicates that the direct WR $AFFT_1$ correlation tends to underestimate the ash fluid temperature for these samples as previously observed.

Figure 2-11 compares the indirect WR $AFFT_2$ correlation against the actual AFFT. The average deviation is +76° F and the standard deviation is 226° F. Only 9 of the predicted $AFFT_2$ fall within the plus or minus 150° F the reproducibility accuracy limit. The WR $AFFT_2$ estimates are more scattered than the WR $AFFT_1$ estimates and are less accurate based on standard deviation. The positive average deviation indicates that the direct WR $AFFT_1$ correlation tends to over-estimate the ash fluid temperature.

Figure 2-10
Comparison of Direct WR Correlations and WMPI/EECP Coal Data

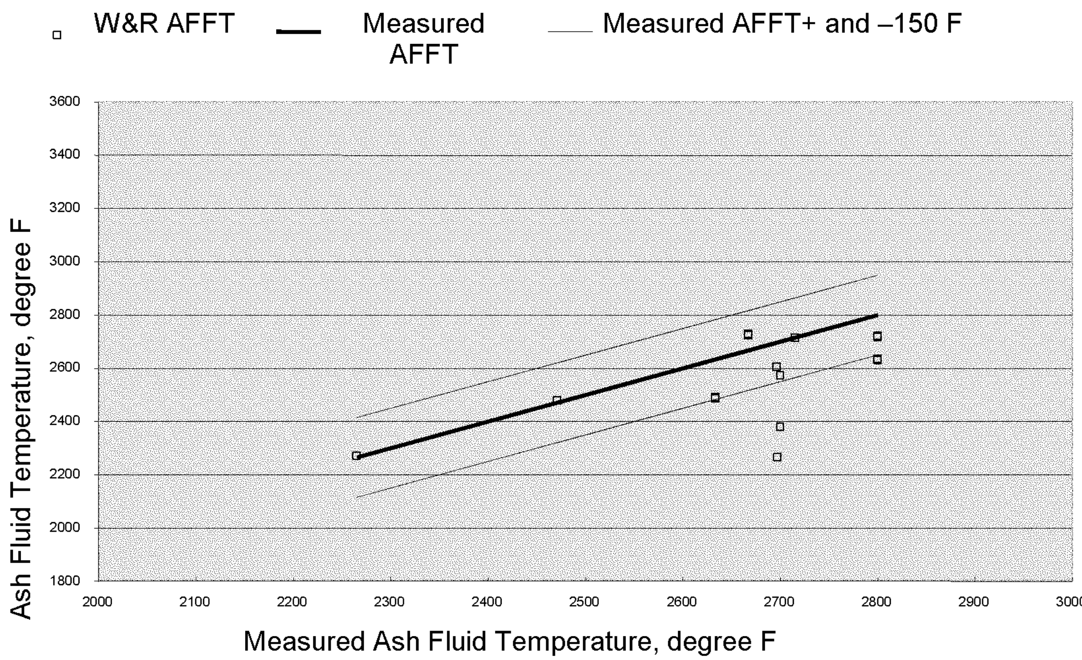


Figure 2-11
Comparison of Indirect WR Correlations and WMPI/EECP Coal Data

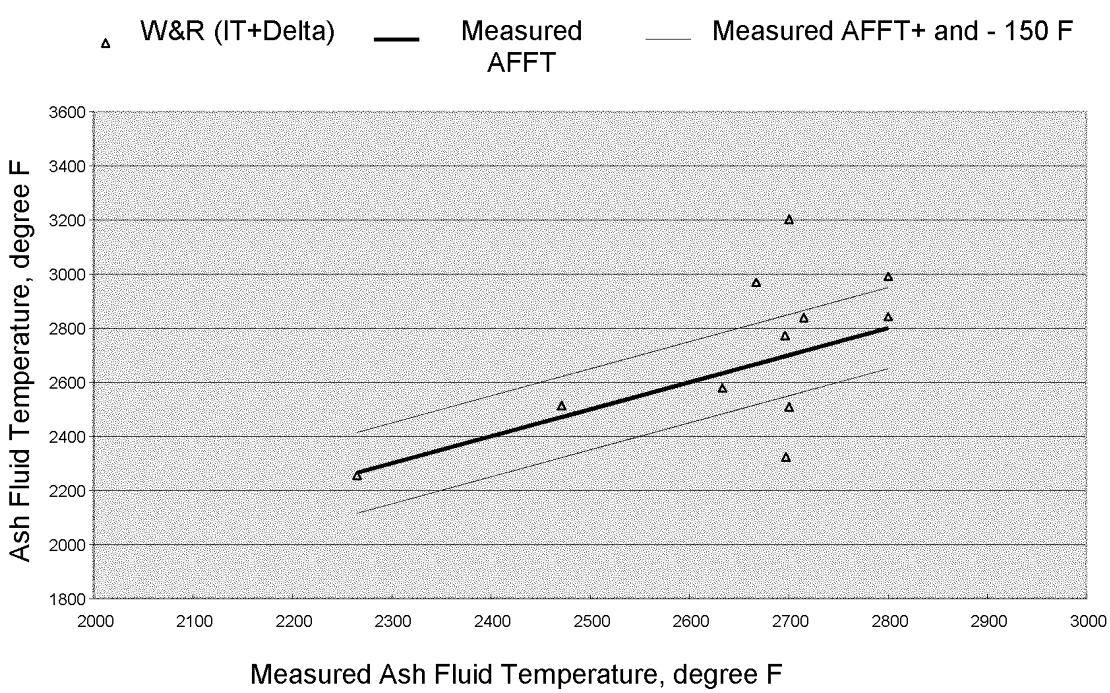
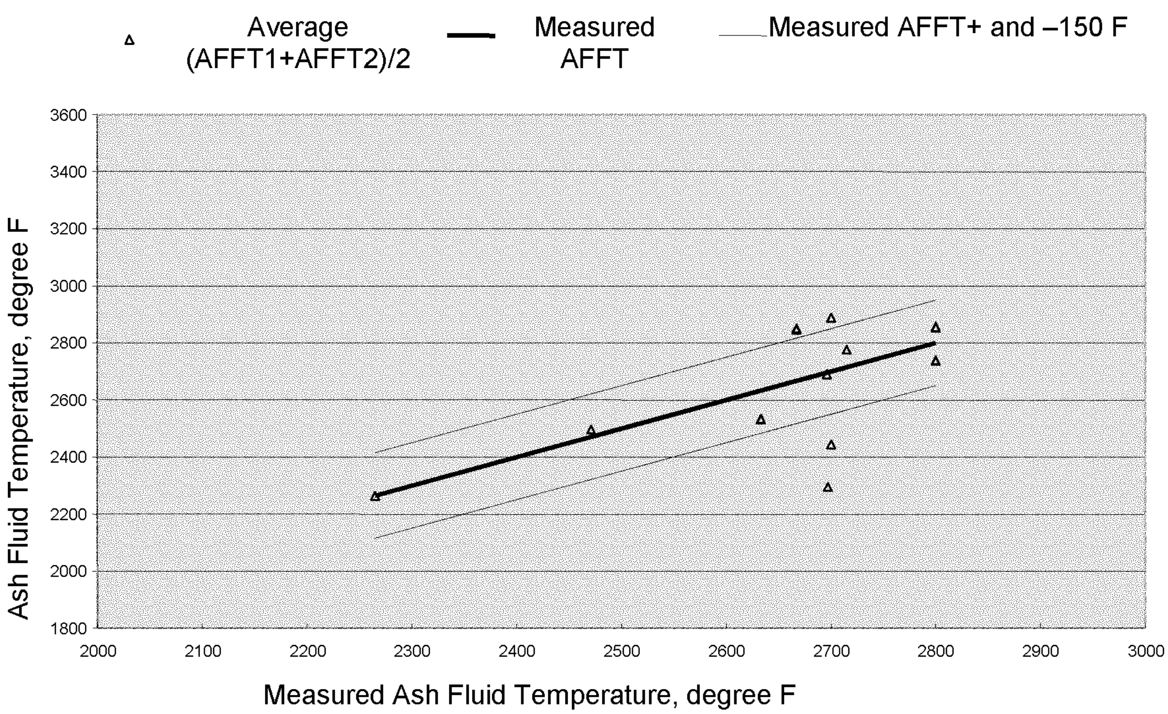


Figure 2-12 compares the average WR $AFFT_1$ and WR $AFFT_2$ estimates against the measured AFFT. The average deviation is -16° F and the standard deviation is 162° F. The average values scattering are about the same as the direct WR $AFFT_1$ predictions, and the accuracy is just slightly better than the direct WR $AFFT_1$ estimates based on standard deviations.

Figure 2-12
Comparison of Average WR Correlations and WMPI/EECP Coal Data



EECP Blended Feeds

For the two laboratory-synthesized blends of potential feedstock, the data in Table 2-4 was prepared.

Table 2-4
EECP Blended Feedstock Data

Data Items	*Blend 1* Weight %		*Blend 2* Weight %	
Anthracite Culm	95		95	
Limestone	5		2.5	
CFB Fly Ash	0		2.5	
	Ash Fusion Fluid Temperature °F	Difference, Measured - Estimated	Ash Fusion Fluid Temperature °F	Difference, Measured - Estimated
Measured	2,471	Measured	2,696	Measured
Direct WR $AFFT_1$	2,478	+ 7	2,607	- 89
Indirect WR $AFFT_2$	2,514	+43	2,773	+ 77
Average $AFFT_1$ and $AFFT_2$	2,496	+25	2,690	- 6

The three correlations (direct, indirect and average) are each within the inherent accuracy of the ASTM D-1857 test.

2.1.3 Conclusion

Winegartner and Rhodes (WR) correlation was found to be quite satisfactory in estimating coal ash fusion temperature, based on the two set of coal data analyzed and some of the preliminary measurements made by WMPI as part of the Phase I EECP Design Basis activities. It can be a useful tool in guiding the EECP program in estimating the coal ash fusion temperature and the amount of fluxing materials may be required for satisfactory gasification operation. Additional data will be added to the evaluation as more ash composition and fusion temperature measurements are contemplated as part of the Phase II RD&T program.

Table 2-5 summarizes the results of the data analyzed.

Table 2-5
Summary of Correlation Assessment
Feedstock Average and Standard Deviations

Data Sources	Data Points	Direct WR $AFFT_1$	Indirect WR $AFFT_2$	Average of $AFFT_1$ and $AFFT_2$ $AFFT_{avg}$
		Average Deviations, Degree F		
US DOE Coal Data Book	60	-186	-36	-111

Nexant Data	30	-63	+83	+10
WMPI Data	13	-108	+76	-16
All Data Points (103)		-140	+14	-63
		Standard Deviation, Degree F		
US DOE Coal Data	60	214	185	168
Nexant Data	30	130	325	195
WMPI Data	13	175	226	162
All Data Points (103)		187	236	173

The WR $AFFT_2$ correlations have the smallest average deviations, but they are the least accurate based on standard deviations. The average, $AFFT_{avg}$, deviations are somewhat better than the $AFFT_1$ values, but the difference is too small to justify the more complicated calculation. Thus, the simpler direct WR $AFFT_1$ correlation is recommended be used for estimating ash fluid temperatures. Also, as a design margin, 150^{o} F should be added to the WR $AFFT_1$ estimates to compensate for the correlation's tendency to under-estimate the ash fluid temperatures.

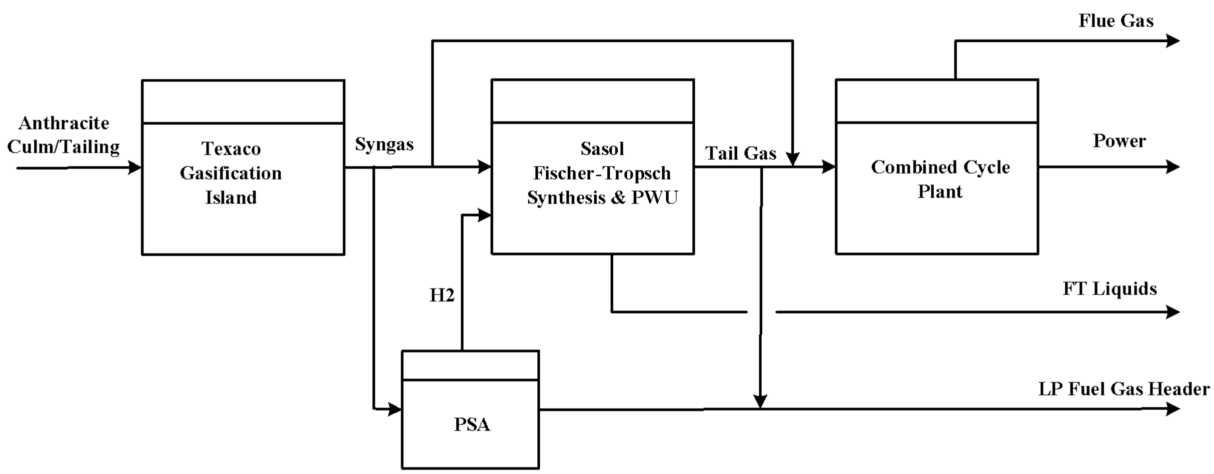
2.2 Preliminary EECP Plant Balances

Preliminary heat, material and utility balances were carried out, based on process performance estimates and utility demands from Texaco and Sasol for the gasification and FT synthesis section respectively, with an objective to establish an integrated process/utility model for future optimization trade-off analysis, and to provide preliminary emission data needed for Phase I Task 7(Preliminary Environmental Assessment) planning.

2.2.1 EECP Configuration

Figure 2-13 shows the overall WMPI EECP block flow configuration.

Figure 2-13 Overall EECP Process Configuration



This Base Case, stand-alone, EECP plant consists of two main process sections: Texaco Gasification, and Sasol FT Synthesis and product work up (PWU). It is designed to use anthracite culm of 20% ash as the primary feed. The design has the operation flexibility of feeding in 25% petroleum coke as feed.

The Texaco gasification section consists of air separation unit; coal storage, receiving and conveying; anthracite culm beneficiation facility; coal slurry preparation; gasification; sour water-gas-shift; syngas cooling; Rectisol acid gas removal; sulfur recovery and tail gas treating; and CO2 product treating and handling.

The Sasol FT synthesis and PWU section consists of syngas polishing; FT synthesis; pressure swing absorption (PSA) for hydrogen recovery and product workup and recovery.

Block flow diagrams depicting the Texaco coal gasification section and the Sasol FT synthesis section are shown in more detail in Figure 2-14 and 2-15 respectively. More detailed process descriptions and material balances will be provided at as part of the overall feasibility study package at a later day.

Figure 2-14 EECP Block Flow Diagram – Gasification Section

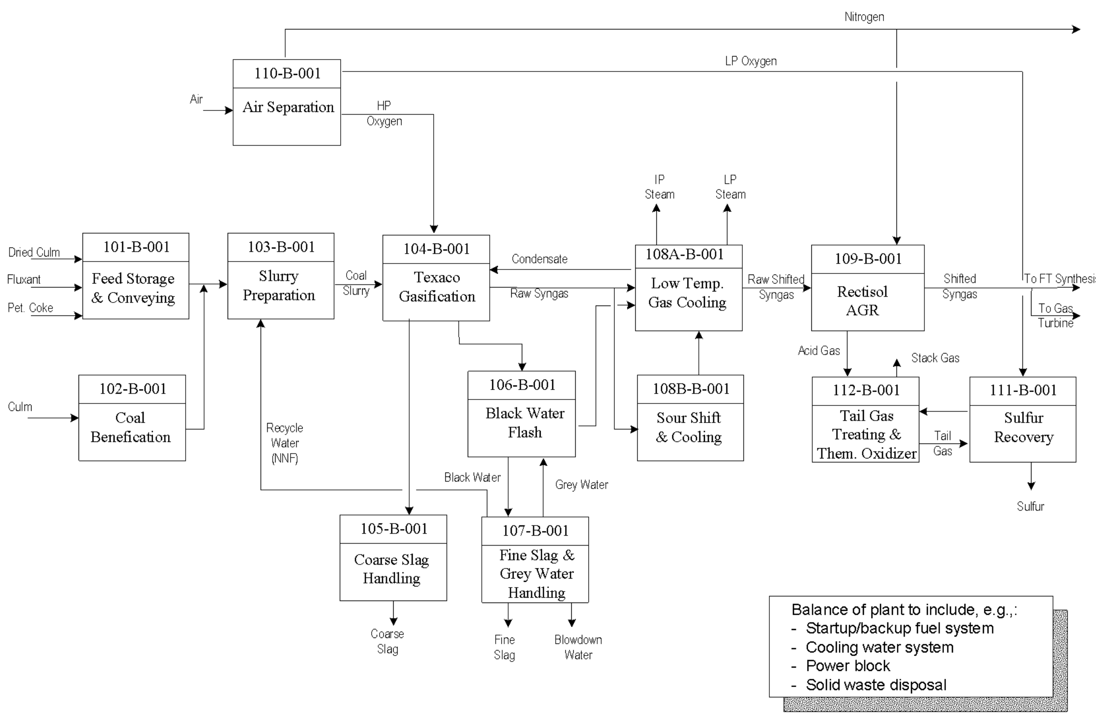
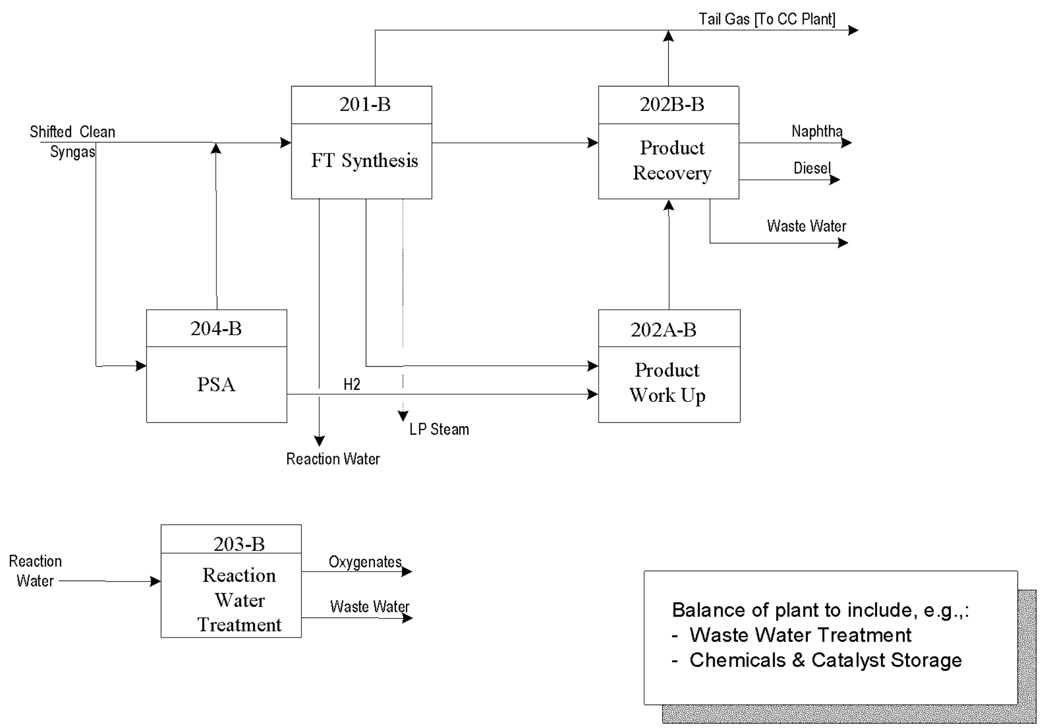


Figure 2-15 EECP Block Flow Diagram – Fischer Tropsch and Product Work Up Section



2.2.2 Preliminary EECP Plant Balance Summary

Preliminary plant balance for the Base Case EECP is given below. It is subjected to update upon receiving the final feasibility process package of the gasification and FT Synthesis & Product Workup section from Texaco and Sasol respectively.

```
CONSUMABLES :
=============
     Dry Coal Feed, Ton/day                              3,534
     Fluxant, Ton/day                                      246
     Oxygen Feed, Ton/day (100% O2 Basis)                3,312
     LP Nitrogen Feed, Ton/day                             397
     Makeup Water from Mine Pool, GPM                    2,366
     Makeup Water from Well, GPM  (1)                    1,403
     Makeup MeOH, Lb/Hr                                    557
     M/U NG to GT & Thermal Oxid, MMSCFD                  0.00
PRODUCTS:
=========
     Upgraded FT Diesel, BPSD                            3,747
     Stabled FT Naphtha, BPSD                            1,286
     Liquid Sulfur, STPD (99.8% Recovery)                 13.4
     Slag & Ash, STPD Dry (Incl C)                       1,004
     Net Power Export, MWe                                25.5
     Net 300 PSIG/590 F Stm Export, LB/Hr                    0
     Fuel Gas Export, MMBtu(HHV)/Hr                          0
```

```
OPERATION SUMMARY:
==================
     % Original Texaco Thruput                          100.0
     % Syngas Bypassing Sour Shift                      64.29
     % Syngas Loss in Gasification Block                 0.00
     % Syngas Bypassing FT Plant                          0.0
     Sasol Syngas Feed H2/CO Ratio                     1.4675
     PSA H2 Plt Feed, % F-T Syngas Feed                 4.759
     F-T Plt Thruput, % Sasol Refer Case                100.1
GROSS POWER GENERATION, kWe   :
================================
         Gas Turbine Power                             87,386
         Steam Turbine Power                           44,562
         Generator Loss                               (7,203)
         --------------------                      ----------
         Turbo-Set Power                              124,745

         Fuel Gas Expander Power                            0
         Expander Generator Loss                            0
         ------------------------                  ----------
         Net Expander Power                                 0

         Gross Plant Power                            124,745

AUXILIARY LOAD CONSUMPTION, kWe:
================================
     Coal Beneficiating & Slurry Prep                   4,209
     Texaco Gasification                                2,002
     Syngas Cooling                                       270
     Air Separation Plant                              54,454
     Oxygen Compression                                     0
     H2S Acid Gas Removal (Amine)                           0
     H2S/CO2 Acid Gas Removal (Rectisol)               15,661
     Sulfur Recovery/Tail Gas Treating                    105
     Sour Water Stripper Pumps & Air Coolers               79
     Sasol FT Synthesis & Product Upgrade               8,554
     High Pressure Boiler Feed Pumps                    3,331
     Low Pressure Boiler Feed Pumps
     Surface Condenser Condensate Pumps                    57
     Makeup Water Pumps                                    33
     Cooling Water Circulation Pumps                    4,588
     Cooling Tower Fans                                 2,111
     Turbo-Set Auxiliary Consumptions                     490
     Plt Air, N2, PSA H2, & FG Compressors              1,435
     Allowance for Balance Of Plant                     1,895
     -----------------------------------           ----------
     Total Auxiliary Load Consumption                  99,274

NET PLANT OUTPUT, kWe                                  25,471
```

Section 3 Phase I Task 4 – Feasibility Design Package Development

Under this task, feasibility study process design packages are to be developed for the EECP gasification island, FT synthesis and offsite utility plants. With most of the major EECP processing plants already identified, Texaco has started with their Type C Feasibility Study package development. Results will be discussed in more detail in the next quarterly technical report.

Section 4 Phase I Task 5 – Market Analysis

Under this task, market analysis is to be performed to assess values of the FT products as refinery blending stocks or as finished fuels. Activities include:

1. FT Product Market Analysis –

    - Research on niche markets to obtain maximum value targets for naphtha and FT diesel, if product is trucked.
    - Demand for FT diesel as a blend stock in non-attainment areas near facility.
    - Value for FT diesel as an EPACT fuel.
    - Current market size for FT diesel as a blend stock.
    - Expected growth rates for the next 10 years for various scenarios.
    - Project current value if FT diesel product were available today.
    - Projected prices for 2005 to 2020.
    - An analysis of transportation options and cost.

2. Refinery Modeling and Recommendations – Identify/recommend two target refineries for FT product considerations. Linear programming modeling of these candidate refineries will be performed to establish the refinery fits for the FT products.

This task is completed by Purvin & Gertz, Inc. under a subcontract to Texaco. Final report was delivered to WMPI. The report contains sensitivity business information that WMPI would prefer not to report it in writing. Under an agreement, DOE can review the report and its findings with WMPI.

Section 5 Phase I Task 6 – Preliminary Site Analysis

As part of Task 6, Nexant, with support from Bechtel personnel, examined alternative modes for transporting large process vessels to the EECP site near the existing Gilberton cogen plant. Sasol's slurry phase FT reactor is expected to be over 18 feet in diameter. Its dimensions and weight are important parameters governing how the vessel should be most cost effectively fabricated and transported to site.

5.1 EECP Large Vessel Transportation Assessment

The FT reactor is the single largest piece of equipment in the EECP design, and thus is used for the analysis. Three alternatives were examined in coordination with design and cost estimating being performed in another task. The first alternative is a single shop fabricated large reactor; the second is two smaller shop fabricated reactors, and the third is a single field assembled large reactor.

The reactors' size and weight data as listed below.

- A single shop fabricated reactor -18.5 feet inside diameter by 60 feet long. The weight is approximately 300 short tons.
- Two smaller shop fabricated reactors -13 feet inside diameter by 60 feet long. The weight is approximately 120 short tons each.
- A single vessel fabricated for field assembly. Six 18.5 feet inside diameter rings, each 10 feet long, are specified for onsite welding and installation. In addition to the 6 rings there are 2 heads at 80,000 to 100,000 pounds each.

As part of the assessment, a trip was made to the Gilberton site to define the transportation routes and the costs of transporting one large shop fabricated reactor versus 2 smaller shop fabricated reactors to the plant in Gilberton, PA. Also, the feasibility and costs are estimated for the overland transportation of the large reactor in multiple ring sections for onsite field assembly and pressure testing.

5.1.1 Proposed EECP Site Location and Conditions

Location: The proposed EECP site is located near Gilberton, PA, north of Interstate 81 and east of Pennsylvania State Highway 61, off Morea Road, approximately 2 miles east of Highway 61 where it enters Frackville, PA. (See attached Maps of Figures 5-1 and 5-2)

Site Features: The site is a Greenfield location at the edge of the Gilberton Power Company's existing plant. Transportation disruptions to normal Gilberton plant operations can be minimized by routing all the construction related traffic via the access road outside the front gate to the east of the plant.

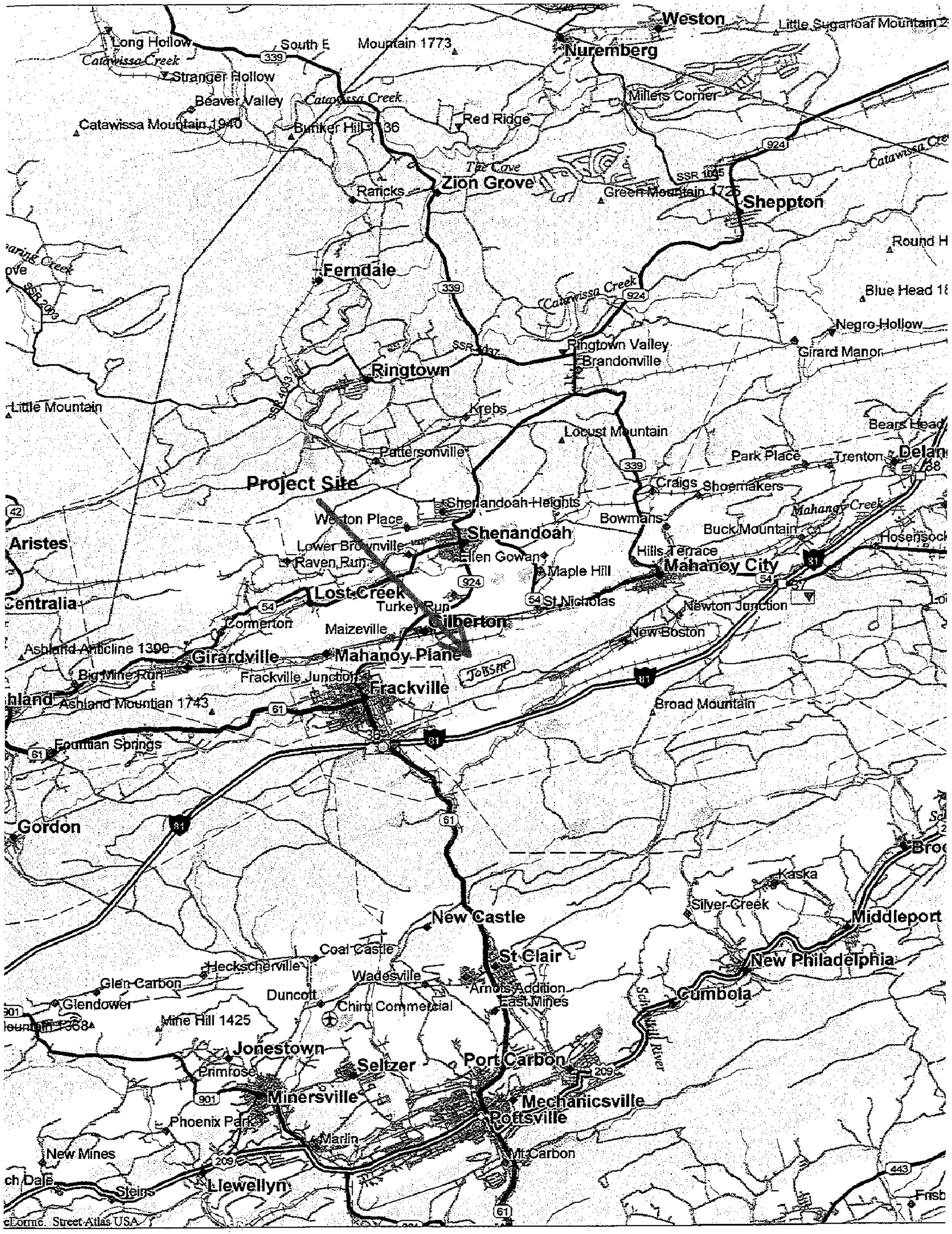

Weston
Nuremberg
Long Hollow
Catawissa Creek
Stranger Hollow
Beaver Valley
Catawissa Mountain 1940
Bunker Hill
Red Ridge
Millers Corner
Zion Grove
Ranicks
Sheppton
Ferndale
Ringtown
Ringtown Valley
Brandonville
Girard Manor
Negro Hollow
Blue Head
Little Mountain
Krebs
Locust Mountain
Pattersonville
Project Site
Park Place
Trenton
Craigs
Shoemakers
Shenandoah Heights
Weston Place
Shenandoah
Bowmans
Buck Mountain
Mahanoy Creek
Aristes
Lower Brownville
Raven Run
Ellen Gowan
Maple Hill
Hills Terrace
Mahanoy City
Lost Creek
Turkey Run
St Nicholas
Newton Junction
Centralia
Cornerton
Maizeville
Gilberton
New Boston
Ashland Anticline 1300
Girardville
Mahanoy Plane
Big Mine Run
Frackville Junction
Frackville
JoBSite
Broad Mountain
Ashland Mountian 1743
Fountian Springs
Gordon
Kaska
Silver Creek
Middleport
New Castle
Coal Castle
St Clair
New Philadelphia
Heckscherville
Glen Carbon
Wadesville
Arnots Addition
Duncott
Glendower
Chiru Commercial
East Mines
Cumbola
Mine Hill 1425
Jonestown
Primrose
Seltzer
Port Carbon
Minersville
Mechanicsville
Phoenix Park
Pottsville
Marlin
New Mines
Mt Carbon
Llewellyn
Steins
Street Atlas USA

Figure 5-1

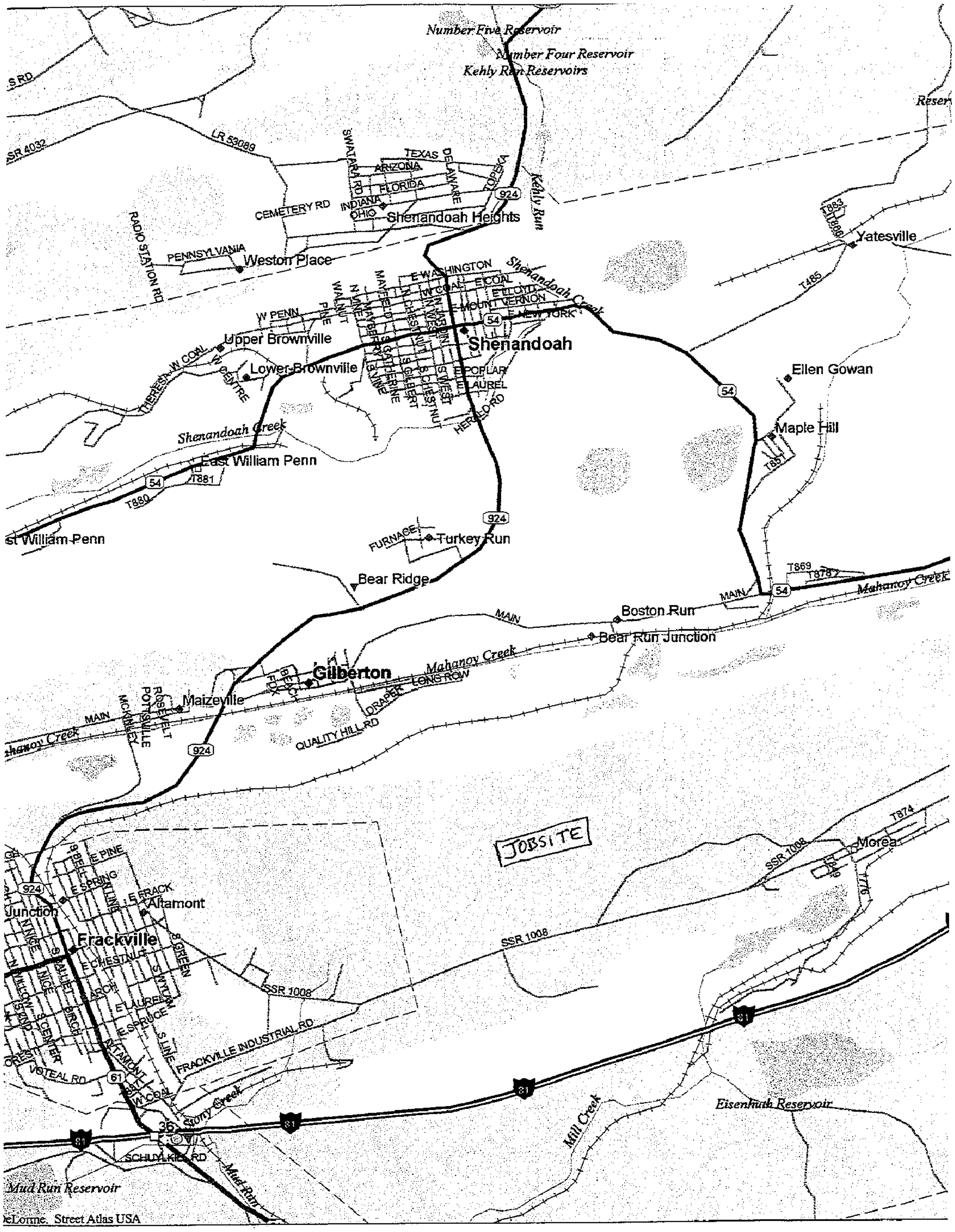

Number Five Reservoir
Number Four Reservoir
Kehly Run Reservoirs
Kehly Run
Shenandoah Heights
Weston Place
Upper Brownville
Lower Brownville
Shenandoah
Shenandoah Creek
East William Penn
Ellen Gowan
Maple Hill
Yatesville
Turkey Run
Bear Ridge
Boston Run
Bear Run Junction
Mahanoy Creek
Gilberton
Maizeville
QUALITY HILL RD
JOBSITE
Altamont
Frackville
Morea
SSR 1008
FRACKVILLE INDUSTRIAL RD
Stony Creek
Mill Creek
Eisenhuth Reservoir
Mud Run Reservoir
Mud Run
SCHUYLKILL RD
DeLorme. Street Atlas USA

Figure 5-2

5.1.2 Summary Results

The conclusions of the 'large vessel transportability to the Gilberton site - shop vs. field fabrication cost comparison' study are briefly listed below.

- It is not feasible to transport a single large (19' ID x 60' T/T) shop fabricated vessel to the Gilberton site,
- It is feasible to transport (heavy haul) two smaller (13' ID x 60' T/T) shop fabricated vessels to the site for erection, and
- It is also feasible to transport the large (19' ID x 60' T/T) vessel in six 10' high rings plus two heads to the site for field fabrication.

The total cost of shipping, fabrication and erection of the vessels is about the same for option (2) and (3). However, when taking into consideration the bulk materials and labor, and accessory equipment associated with each option, there should be cost saving advantage for a large field-fabricated vessel vs. two smaller shop-fabricated vessels. EECP design and cost estimation for large vessels such as Texaco's gasifer, and Sasol's FT slurry reactor shall follow this guideline.

Details of the transportation study are discussed in the following sections.

5.2 TRANSPORTATION

In order to complete the assessment, truck, rail and barge transportation modes were examined. Ship ports where the equipment would begin overland travel to the site were also evaluated.

5.2.1 Site Access By Truck

Access to the EECP site would be via Interstate 81 to State highway 61. This intersection is approximately ¾ mile south of Morea Road, which runs east and west from the site. Highway 61 is approximately 2 miles west of the site when traveling Morea Road.

The following are guidelines for the transportation of equipment and materials to the site.

- Truckloads up to 8.5 feet wide and up to 13.5 feet in loaded height are legal loads and require no permitting by the state of Pennsylvania. The legal load weight is 80,000 lbs. gross (tractor + trailer + load).
- Truckloads over 8.5 feet wide and up to 12 feet wide require Pennsylvania permits. Truckloads over 13.5 feet loaded height up to 15 feet loaded height require permits. Truckloads grossing more than 80,000 pounds and up to approximately 130,000 pounds require permits.

- Anything larger than 12 feet wide, over 15 feet high and over 130,000 pounds gross weight is defined as a “Superload”, and requires permitting and routing by the state permit office located in Harrisburg, PA. The permit process can consume a month or more, depending on the number of bridges that must be reviewed for the move.

Routes south, southeast from the site on State Highway 61 and State Highway 73 (not shown in Figure 5-1 and 5-2) toward Philadelphia were analyzed. There are small towns, narrow roads, low overpasses, old bridges, power lines, telephone lines, and traffic congestion on the routes. Neither route was judged practical or feasible for transport of the single large (18.5’ ID) reactor.

5.2.2 Site Access By Rail

Direct rail access to the site is not available. National rail access to the area is with Norfolk Southern and CSX Railroads. They interline with the regional railroad, which is the Blue Mountain Reading and Northern Railroad. The closest railroad siding is approximately 5 miles from the site near the town of Gilberton.

Rail transport alternatives are limited primarily by bridges and tunnels. Oversize cargo requires obtaining clearance from the railroad. Cargo up to 12 feet wide moves via rail with regularity, but once 12 feet wide is exceeded, it is difficult to obtain clearance. Heights up to 19 feet above the rail are typically acceptable. Transporting a load wider than 12 feet or higher than 19 feet, (assuming a clearance is obtained), may have to move via special trains with costs as high as $65 per mile, in addition to the freight cost.

In addition to the rail shipment, cost and risk considerations must be made for the following issues.

- Added cost for rigging and tie down (securing the load on the railcar)
- The cost and schedule issues of using a temporary laydown storage, if the construction team can not begin assembly/erection upon arrival.
- Rail transport typically allows less control of transit times and delivery scheduling by the construction team. Track transport is more flexible as regard schedule changes.

The single large reactor and the multiple ring sections could not be moved by rail. The 2 smaller reactors could move by rail, but truck transport is judged be a better option.

5.2.3 Site Access By Barge

There is no barge access to the site. The closest barge facility is the USX plant at Fairless Hills, PA (also known as Novolog). The facility is also accessible by ship. It is approximately 90 miles from the EECP site. If the equipment is shipped from the supplier by water, this facility would be used to receive and transfer the load to truck for overland transport.

5.2.4 Ports of Import

There are three practical ports where a heavy lift could be received and transferred to another mode of transportation. The port and their locations are noted below.

- Port of Elizabeth, NJ (New York) - This port is approximately 120 miles east of the EECP site. For a heavy lift ship, it is an inducement port.
- Port of Philadelphia, PA - This port is approximately 100 miles south, southeast of the EECP site. For a heavy lift ship, it is also an inducement port.
- USX at Fairless Hills, PA, also known as Novolog - This port is about 90 miles southeast of the EECP site. It is also an inducement port. It is used by Air Products for shipping some of their equipment.

The ports of Elizabeth, NJ, and Philadelphia, PA, are congested and make the import of heavy lift loads difficult. Port Elizabeth also would require overland shipping permits for New Jersey. The best port choice is the USX, Fairless Hills facility. The port is experienced with large loads, and be the best option for highway routing and obtaining Pennsylvania permits.

5.3 REACTOR AND TRANSPORTATION COST ESTIMATES

Costs for shop fabricated and field assembled welded vessels were obtained by informal budget quotes from three potential suppliers. Costs from the data are summarized below for the items.

- Single large vessel 18.5 feet diameter consisting of multiple “can” rings and top and bottom heads. The vessel components will be shop manufactured and field erected. The single large vessel, shop fabricated, was not estimated because it can not be transported to the site.
- Two smaller vessels of 13 feet diameter to be erected as single units, or possibly as two pieces per vessel.

Table 5-1 shows the costs estimated by Nexant and Bechtel for the FT reactors (reactor shell only). The estimate indicates that the total cost for a single vessel, field erected from cans and heads is about $500,000, or 20% less than erection of two smaller vessels. The estimates are expected to be in the range of 30% accuracy. If other issues such as process reliability or operation and maintenance are affected by the selection of single or multiple vessels, the costs may be reviewed when further engineering data is available.

Table 5-1
FT Vessel Fabrication, Transportation and Erection Cost Estimates
$1,000s

Items	A Single Vessel Field Assembled from Cans and Heads	B Two Vessels Shop Fabricated, Field Erected	Difference in Costs (A-B)
Vessel and Erection Cost	1,500	1,500	-----
Shipping to Port of Fairless Hill, PA	230	260	-30
Overland Transport to EECP Site	120	300	-180
Foundations, Piping and Other Direct Field Costs	400	550	-150
Total Direct Cost	2,250	2,610	-360
Construction Indirect Costs	200	300	-100
Subtotal	2,450	2,910	-460
Engineering	240	290	-50
Total	2,690	3,200	-510

Section 6 Project Management

6.1 BIWEEKLY PROJECT STATUS REPORT

Informal Biweekly Project Status Reports are transmitted to keep the DOE Project Manager updated of all work in progress.

6.2 PROJECT MILESTONE PLAN AND LOG

Project Milestone Plan and Milestone Log are submitted on time as prescribed by the contract to keep DOE management informed of work-in-progress and accomplishments against major project milestones planned.

Section 7 Experimental

7.1 EXECUTIVE SUMMARY

7.2 EXPERIMENTAL

7.3 RESULTS AND DISCUSSION

7.4 CONCLUSION

7.5 REFERENCE

NOT APPLICABLE - The current project is a design feasibility and economics study, leading to detailed engineering, construction and operation of an EECP plant. It's not a typical research and development (R&D) project where a topical report format described in this section applied. There was no experimental work performed. This section is included only to fulfill DOE's prescribed reporting format.

List of Acronyms and Abbreviations

DOE.. U.S. Department of Energy
NETL.. National Energy Technology Laboratory
WMPI... Waste Processors Management, Inc.
EECP.. Early Entrance Co-Production Plant
FT .... Fischer-Tropsch
RD&T .... Research, Development & Testing
ISBL .... Inside Battery Limits
OSBL.. Outside Battery Limits
AFFT .... Ash Fusion Fluid Temperature
IT.. Initial Deformation Temperature
ST .... Softening Temperature
HT .... Hemispherical Temperature
WR .... Winegartner and Rhodes
ASTM... American Standard Testing Methods
CO2 .... Carbon Dioxide
PWU .... Product Work Up
PSA .... Pressure Swing Absorption
ID .... Inside Diameter
T/T.. Tangent to Tangent